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SECOND-ORDER PROBLEMS IN STUDIES OF PERCEPTUAL DEVELOPMENT.

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RECENT RESEARCH FINDINGS ON THE PERCEPTUAL DEVELOPMENT OF YOUNG INFANTS WERE SURVEYED, AND THE NEED FOR SYNTHESIZING THESE NEW FINDINGS INTO WORKABLE CONCEPTS WAS SUGGESTED FOR THE FRUITFUL STUDY OF HIGHER ORDER CONSIDERATIONS IN THE FUTURE. A DISCUSSION WAS MADE ON THE DEVELOPMENTAL ISSUES OF--(1) SUPERORDINATE CATEGORIES OF PERCEPTUAL FUNCTION, INVOLVING THE PROCESS OF TYING CONCEPTS LIKE FORM DISCRIMINATION AND DEPTH PERCEPTION TO THE DATA ON INFANT BEHAVIOR, (2) SUPERORDINATE BEHAVIORS, INVOLVING THE STUDY OF THE DEPENDENCY OF COMPLEX SKILLS LIKE VISUALLY DIRECTED REACHING, CREEPING, AND WALKING UPON THE ACQUISITION OF LESS COMPLEX BEHAVIORS, (3) TRANSITION FROM INNATE STEREOTYPED BEHAVIOR TO MATURE FORMS, INVOLVING THE STUDY OF IMPLICATIONS OF THE GRADUAL CHANGE FROM TACTUALLY INDUCED ROOTING BEHAVIOR AT BIRTH TO MORE FLUID AND VARIABLE BEHAVIOR AS THE INFANT DEVELOPS, (4) SCHEDULES OF APPROPRIATE EXPERIENCES, INVOLVING A DETERMINATION OF THE MOST SUITABLE EXPERIENCES FOR OPTIMAL DEVELOPMENT, (5) EARLY PERCEPTUAL-MOTOR BEHAVIOR AND COGNITIVE DEVELOPMENT, INVOLVING THE EMPIRICAL TESTING OF THE IDEA THAT THE INFANT'S PREHENSORY CONTACT WITH OBJECTS MARKS THE BEGINNING OF ACQUISITION OF COGNITIVELY RELEVANT INFORMATION AND TIES SEVERAL SENSORIMOTOR SUBSYSTEMS (SEEING, REACHING, GRASPING) TOGETHER, AND (6) ANALYTICAL STUDIES OF THE ROLE OF EXPERIENCE, INVOLVING THE ISOLATION AND STUDY OF INDIVIDUAL FACTORS OF ENVIRONMENT, MOTILITY, AND TACTUAL STIMULATION. THE AUTHOR SUGGESTED THAT THESE SIX HIGHER-ORDER ISSUES SHOULD SERVE HEURISTICALLY AS INDICATORS OF THE DIRECTIONS RESEARCH SHOULD TAKE. THIS PAPER WAS PRESENTED AT THE INSTITUTE FOR JUVENILE RESEARCH, CHICAGO, SEPTEMBER 1, 1965. (JH)

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# SECOND-ORDER PROBLEMS IN STUDIES OF PERCEPTUAL DEVELOPMENT

Burton L. White, Harvard University

Presented at the Institute for Juvenile Research, Chicago
September 1, 1965

As a student back in 1957, I read a book by Lois Murphy describing the development of a gifted child from his second through his fifth year of life. The focus of that work was on the quality and scope of the "coping" or "adaptive" abilities of an exceptionally capable child. The book fascinated me because it was the first detailed longitudinal study of "normal" development I had read. (I might add that this kind of study is a rarity even now.) I was left both inspired and intrigued, for not only was the subject matter fascinating but, furthermore, Murphy had pointed out that much of the make-up of the five-year-old graduate of her program had been clearly discernible in the two and one-half-year old. What intrigued me was the age period not covered by the study -- the first two and one-half years. And, more specifically, the possibility that experience during the postnatal period might play an important role in development.

Shortly thereafter, under the tutelage of Peter Wolff and Richard Held, I began to study human infants. Specifically, I have concentrated on the problem of how the proficient six-month-old infant gets that way.

Guidance for my efforts have come from three sources: Lorenz, Piaget, and Held and Hein. Lorenz advises anyone studying a relatively exotic creature to become thoroughly acquainted with the animal before using him as an experimental subject. When I attempted to ignore this dictum, I ran afoul. Considering the enormous expense involved in longitudinal experimental work with infants, it is obvious that one cannot afford repeated false starts due to simple ignorance of the fundamentals of early behavior. Since my abortive early

attempts, I have spent, and continue to spend, an enormous amount of time playing "fly on the wall" with hundreds of normal infants ranging in age from one day to six months. I believe that this has been time well spent. From Piaget and Held and Hein have come theoretical frameworks around which one may orient his explorations. Without such an orientation, infant behavior can be bewildering. I do not mean to imply that these two theoretical positions are necessarily correct or even sufficiently detailed. But Piaget does suggest a structure describing the overall transition from innate sensorimotor functions to representational intelligence; and Held and Hein propose a narrow but reasonably specific set of hypotheses concerning the mechanism by which development proceeds.

Many of the ideas in this paper should not be construed as solely mine. Richard Held, Alan Hein, Joseph Bauer, and I at Massachusetts Institute of Technology consider our efforts to be collaborative. Our group studies human adults, infant monkeys, cats and humans.

As we all know, the last decade has seen a tremendous burgeoning of interest in infant perceptual research. Undoubtedly, Robert Fantz deserves much gratitude for his stimulating research. The renaissance of interest in Piaget's sensorimotor theory has probably been another important catalytic factor. For whatever reasons, work in this area is now in high gear. Brown University, for example, has at least ten post-doctoral people working full-time in infant research, whereas fifteen years ago the number was virtually nil. The story seems to be the same in many places. It seems to me that we can now venture a cautious attempt at an overview of the situation. In fact, I feel even more strongly than that. I feel that it would be very healthy for the field as a whole if we occasionally took the time to ask where we are going -- whether we are acquiring information that interlocks and leads somewhere or merely collecting intellectual curiosities under the protective mantle of science for science's sake.

It seems to me that the major portion of our findings of the last ten years concerns the detection of isolated capacities. Gibson

and Walk studied "depth perception" using their now famous "visual cliff". Fantz has dealt with visual preferences and form discrimination, and my colleagues and I have recorded the development of visually-directed reaching, visual accommodation, visual attention, and related behaviors. Each of these, and similar research programs, has faced the formidable task of generating measuring devices or observational techniques dependable enough to yield reliable data, and innocuous enough for use with human infants.

Our studies of infant perception are rather unusual in that we have the opportunity to do longitudinal research. For several years now we have been able to work with a fair number of babies from birth through six months of age.

Lately, as information has accumulated, higher-order considerations have been demanding attention. I have in mind the following kinds of developmental issues:

1. Superordinate Categories of Perceptual Function - Concepts like form discrimination and depth perception must be tied to the realities and complexities of infant behavior. Gibson and Walk talk about depth perception in terms of the crawling responses of the eight-month-old child. Fantz reports increased visual orienting to solid rather than to two-dimensional targets after two months of age. More recently, Bower has noted cardiac responses to "looming" objects in infants less than two months old. We have noted visual accommodative and convergence responses to nearby objects at six weeks, accurate swiping at objects at two months, accurate reaching at three to five months, blinking to an approaching object beginning at two months, and the placing response at about eight months. What shall we call depth perception? My point is that all of these data must be considered when studying the development of depth perception. A similar case can be made for form discrimination.

2. Superordinate Behaviors - Visually-directed reaching depends upon the acquisition of several simpler skills such as visual-motor pursuit, sustained fixation, orienting of the head and trunk, the integration of the grasp with the arm approach, and a relatively sophisticated capacity to bring the hand quickly to an infinite number of points in nearby space. Creeping and walking are other examples of superordinate behaviors. We need to know how each prerequisite system develops and the manner in which they become subsumed under the superordinate action.

3. Transition from Innate Stereotyped Behavior to Mature Forms - Some twenty years ago, Myrtle McGraw wrote of an early period of sub-cortically mediated behavior which gradually disappeared during the first half-year of life as the higher centers matured. During the first few months of life, behavior was stereotyped and mechanical. Thereafter, it became more fluid and variable. Ling, in her study of the development of fixation, described a five-step process which expressed the same general theme. I have seen this kind of qualitative shift in several developing response systems. For example, tactually induced rooting responses are present at birth. During the first month, response accuracy increases and latency decreases. In general, the infant gradually develops a machine-like stereotyped performance. During the next two months, the behavior drops out and is replaced by what looks like voluntary multi-step searchings with the mouth.

The development of visual-motor pursuit looks quite similar. Under restricted conditions, rudimentary pursuit is present at birth, but it is difficult to elicit, discontinuous, and usually limited in range. During the next six weeks, there is an orderly development into a remarkably dependable, smooth performance. At six weeks and for about another month and a half, virtually any infant can be made to pursue a moving target (Figure 1) steadily as long as he is awake. By four to five months, infants

usually throw a casual glance at the target and quickly turn away as if to say, "If that's the best you can do, don't waste my time."

This kind of sequence seems to hold for the blink response and visual accommodation and even perhaps for visually-directed reaching. The implications of such developmental sequences are important. Perhaps most basic is that in experimental interventions a recognition of the stage of development of a subject may make it considerably easier to shape and predict behaviors. In addition, it is worth considering whether the conditions for learning are necessarily comparable for different levels of function.

4. Schedules of Appropriate Experience - What kind of experience is most suitable to ensure that development proceeds optimally? Surely the mountains of data from deprivation studies have convinced most of us that early experience makes a great deal of difference, at least for the short run. Obviously, rearing conditions which are designed without adequate knowledge of the infant's rapidly changing abilities and predispositions won't do in any scientific approach to the problem.

We have been reasonably fortunate during the last few years in our attempts at systematic enrichment of early perceptual experience. We plan our studies around recently acquired information on accommodative ability, the development of interest in the visual surround, and the tendency to swipe at objects, etc., coupled with existing facts mostly generated by Piaget and Gesell. Some examples of modified rearing conditions may be seen in Figures 2, 3 and 4.

But, although we've been moderately successful, our knowledge is crude and strikingly limited. A good indication of the almost limitless areas that need exploring is the detailed work

on young infants being done by Lipsitt, Sequeland, Kaye, Salatapek, Hershensen, Ames, Fantz, Bower, and many others. And most of these investigators concentrate largely on the first week of life, and usually on one sense modality -- vision. My hunch is that tactual experience is probably at least as important a topic for study during the first two months of life as vision.

5. Early Perceptual-Motor Behavior and Cognitive Development - During the first month of life, our experience indicates that the human infant seems relatively uninterested in his sensory surround except for scattered intervals of time, rarely exceeding a few minutes in length (Figure 5). Towards the middle of the second month, however, a marked change sets in. Though unable to move his torso, the infant begins to exhibit a rapidly increasing interest in his immediate environment. At first this takes the form of head and eye movements predominantly, since his hands are not yet normally open sufficiently for the purpose of tactual exploration. Within two to six weeks, the infant begins to observe his own hand and subsequently spends hundreds of hours gaining visual control over its motions. Simultaneously, tactual explorations become a regular part in the daily routine. It must be a curious sensation after having built up familiarity with the tactual experiences of one's hands individually to experience their coalescence as the hands engage in mutual fingering for the first time. It is this intersection of two or more previously independent sensorimotor sub-systems which Piaget, and von Euxkill before him, have used to provide the theoretical basis for a fundamental cognitive development -- the object concept.

In Piaget's system, a target, such as a small toy, has no conceptual existence for the newborn infant. It may serve to evoke innately-organized responses such as grasping and pursuit, but once these actions cease, there is no reason to assume that

the toy "exists" in any conceptual way for the neonate. When, however, the infant develops to the point that he makes a prehensory contact with the toy, something qualitatively new appears. That one toy has elicited visual fixation, appropriate arm movements, and tactual contact followed by grasping. Several previously separate action systems intersect at the toy. The toy acquires the beginnings of an independent conceptual existence in so far as it is no longer merely a part of any single action pattern, but now ties several sub-systems together. True cognitive representation doesn't develop until many months later in Piaget's system, but prehensory efforts such as reaching do constitute the major early vehicle for this achievement.

I don't mean to claim that Piaget's theory is necessarily correct in this respect. But I can't think of a more convincing one at this time. Our attempts at manipulating prehensory development have definitely shown that there is enormous plasticity in this system as a function of early experience. Some of our experimental subjects are swiping at and reaching for objects much earlier and far more often than they would ordinarily have (Figures 6, 7 and 8). To the extent that Piaget's ideas have validity, these very young subjects should be acquiring enormous amounts of cognitively relevant information. Empirical tests of such ideas would seem in order.

6. Analytical Studies of the Role of Experience - Our enrichment conditions have usually produced increased motility of several kinds, as well as increased opportunities to view various visible forms and colors. We have induced head and trunk motions by placing infants on their stomachs and also by suspending appropriate objects over their upper bodies. We have evoked repeated, monitored prehensory movements, while simultaneously populating the previously bland visual surround. These procedures were utilized simultaneously in our earlier

studies because we needed an answer to the general problem of whether or not sensorimotor development was significantly affected by experience. More highly focused studies would have been premature and very risky in view of the immaturity of the research effort.

Such multiple independent variable manipulations must be replaced by more analytical studies if we are to attain precision in our understanding. The effect of increased motility versus those of enriched visible circumstances must be isolated. Subsequent analyses of different kinds of movements such as head and trunk versus arm and hand and rotation versus translation should be investigated. Comparable analyses of the sensory factors also ought to be done.

I have listed several kinds of higher-order issues which seem to demand consideration if we are to gain a greater depth of understanding of perceptual-motor development. I don't think it would be wise at this time for us to abandon parametric studies of isolated functions to concentrate on these larger issues. But I do think these issues may serve an heuristic purpose as indicators of which directions to pursue. For the next twenty years or so, I would prefer that we expend our major efforts towards the generation of better tools for gathering information, such as the photographic devices used by Hershenson and Salatapek, the conditioning apparatus used at Brown, the Polygraph procedures used by Dayton and Jones, Bower, Frances Graham, and our group (Figures 9 and 10), etc. With such techniques and patience, we may be able to multiply our current knowledge about infant behavior one hundred-fold. At that point, when we know nearly as much about infants as we do about horticulture, we should be in a good position to approach higher-order issues with confidence.

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FIGURE 1 VISUAL PURSUIT TARGET

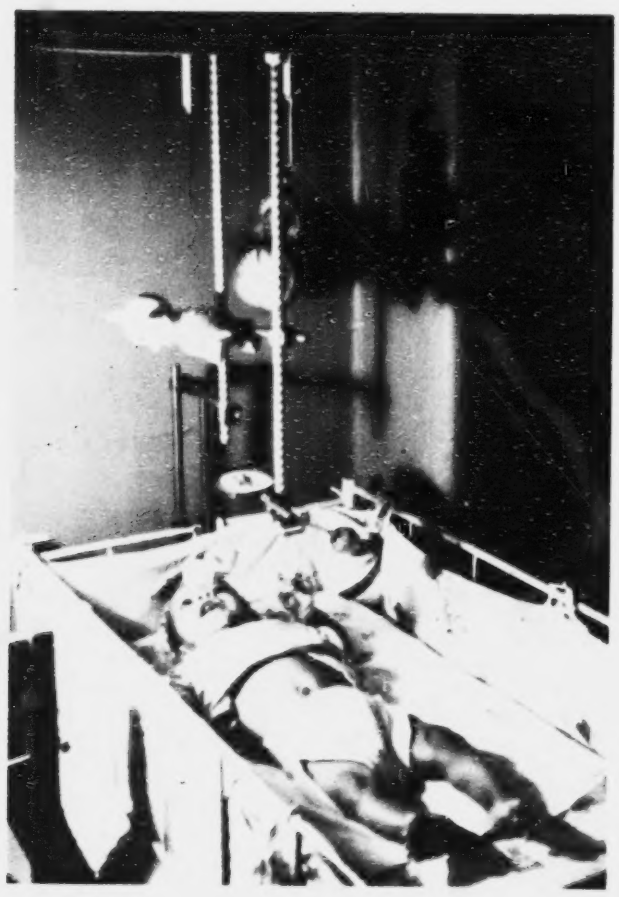


FIGURE 2 MASSIVE ENRICHMENT CONDITION

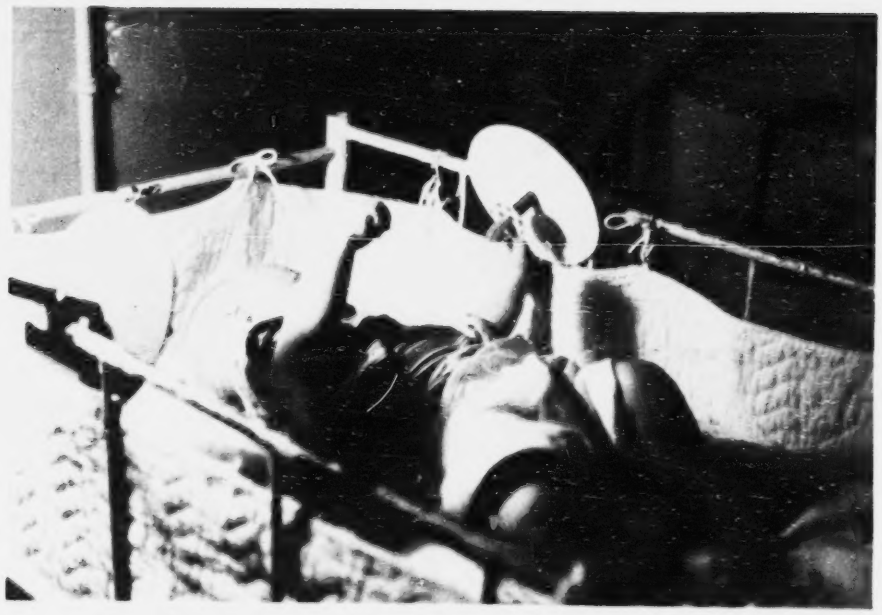


FIGURE 3 MODIFIED ENRICHMENT CONDITION (DAY 37 - 68)

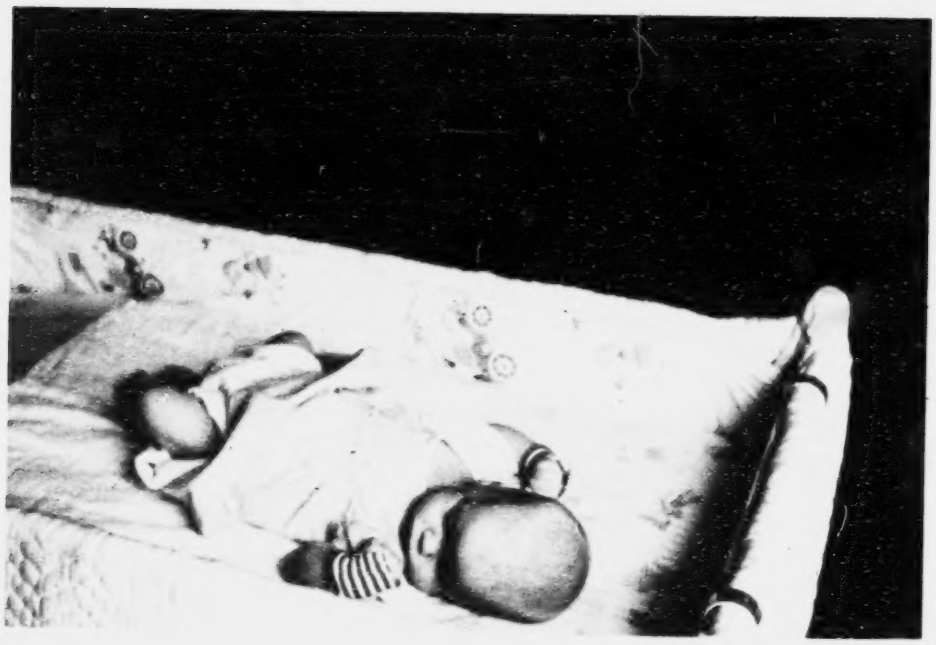


FIGURE 4 BLINK STUDY CONDITIONS

FIGURE 9 BLINK APPARATUS

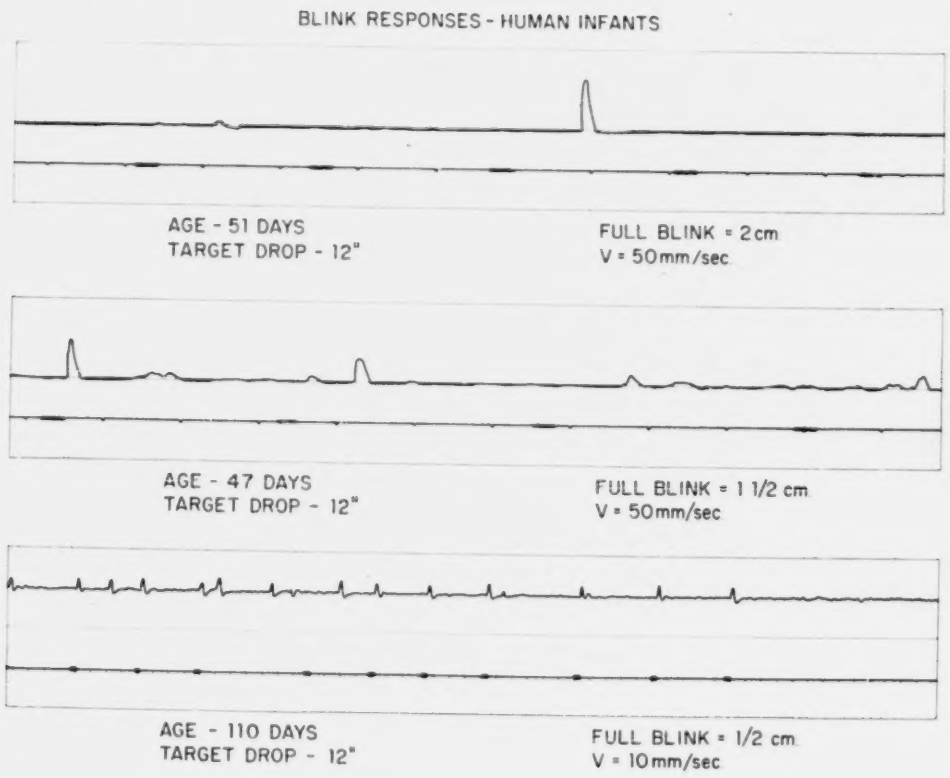
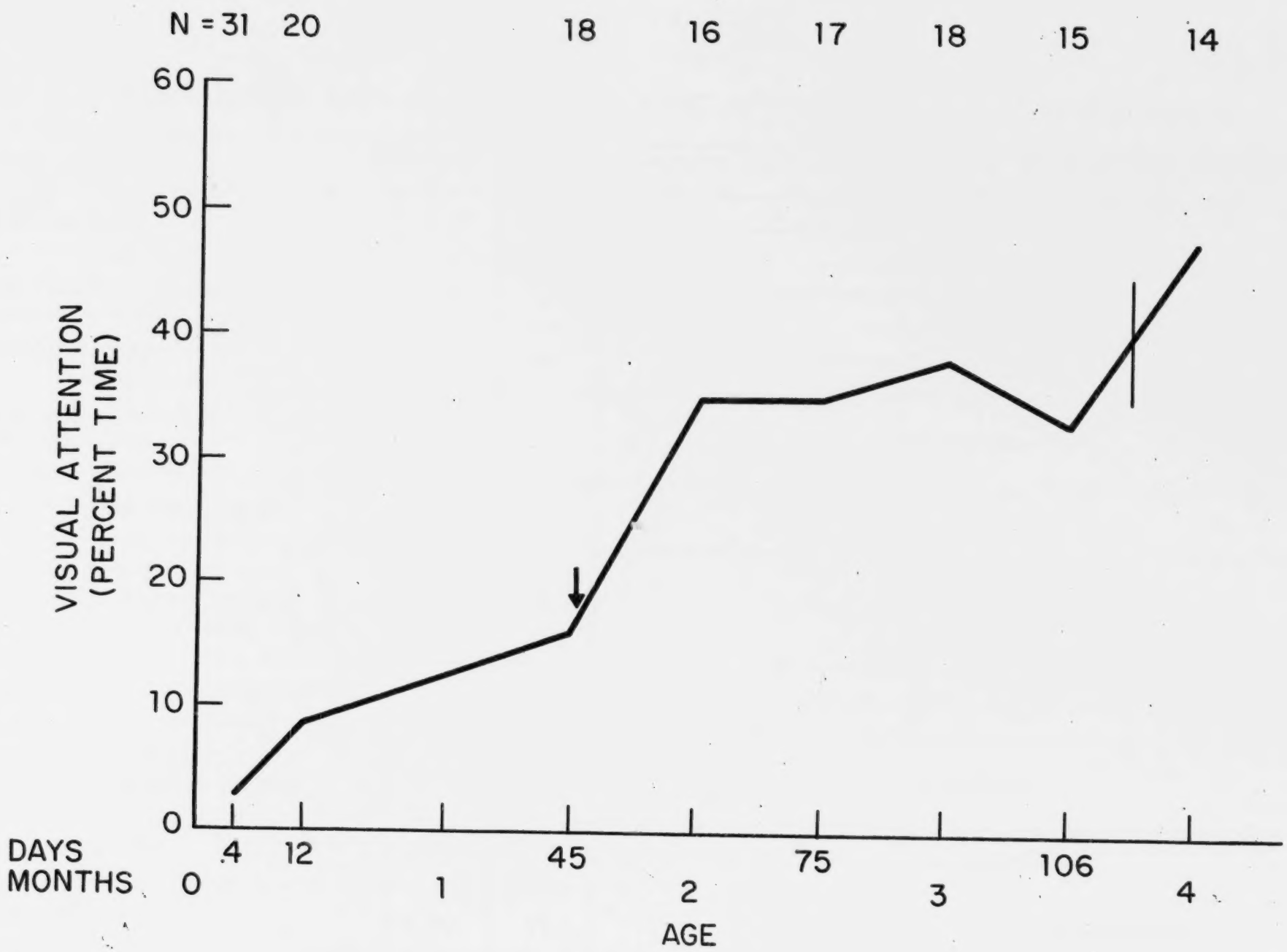

BLINK RESPONSES - HUMAN INFANTS
AGE - 51 DAYS
TARGET DROP - 12"
FULL BLINK = 2cm
V = 50mm/sec
AGE - 47 DAYS
TARGET DROP - 12"
FULL BLINK = 1 1/2 cm
V = 50mm/sec
AGE - 110 DAYS
TARGET DROP - 12"
FULL BLINK = 1/2 cm
V = 10mm/sec

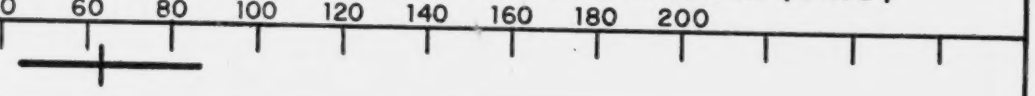
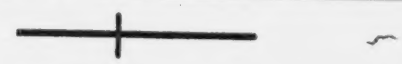
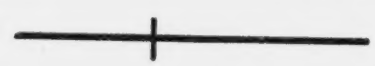
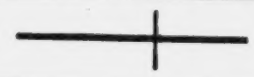
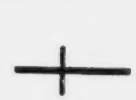
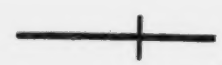
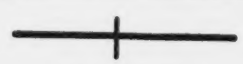
FIGURE 10 BLINK RECORDS




VISUAL ATTENTION DATA - CONTROL GROUP

FIGURE 5 Note: THE ARROW AT 45 DAYS INDICATES THE MEDIAN AGE AT WHICH SUSTAINED HAND REGARD APPEARED. THE VERTICAL BAR AT ABOUT 110 DAYS INDICATES RELOCATION TO LARGE OPEN-SIDED CRIBS.

## NORMATATIVE DATA ON THE DEVELOPMENT OF VISUALLY-DIRECTED REACHING *

| RESPONSE | OBSERVED IN | TOTAL N | MEDIAN AND RANGE OF DATES OF FIRST OCCURRENCE (DAYS) 20 40 60 80 100 120 140 160 180 200 |
|---|---|---|---|
| SWIPES AT OBJECT | 13 | 13 |  |
| UNILATERAL HAND RAISING | 15 | 15 |  |
| BOTH HANDS RAISED | 16 | 18 | |
| ALTERNATING GLANCES (HAND AND OBJECT) | 18 | 19 |  |
| HANDS TO MIDLINE AND CLASP | 15 | 15 |  |
| ONE HAND RAISED WITH ALTERNATING GLANCES, OTHER HAND TO MIDLINE CLUTCHING DRESS | 11 | 19 |  |
| TORSO ORIENTED TOWARDS OBJECT | 15 | 18 | |
| HANDS TO MIDLINE AND CLASP AND ORIENTED TOWARDS OBJECT | 14 | 19 |  |
| PIAGET-TYPE REACH | 12 | 18 |  |
| TOP LEVEL REACH | 14 | 14 | |

* THESE DATA WERE COMPILED BY COMBINING THE SCORES OF CONTROL AND HANDLED INFANTS (WHICH DID NOT DIFFER SIGNIFICANTLY)

FIGURE 6

THE DEVELOPMENT OF VISUALLY-DIRECTED REACHING. STUDY B-MASSIVE ENRICHMENT.

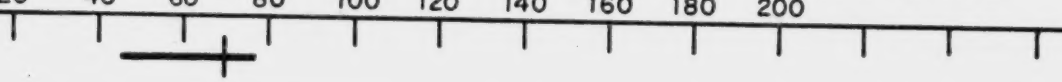
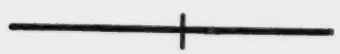
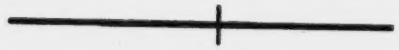
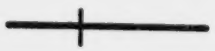
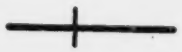
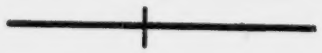
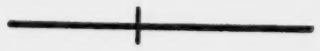
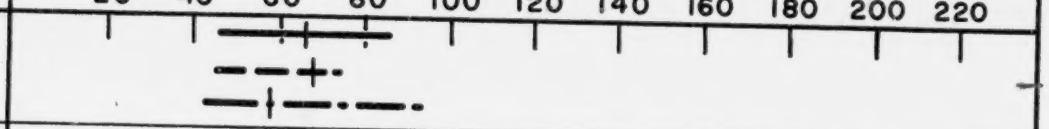
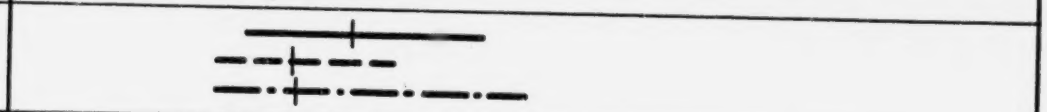
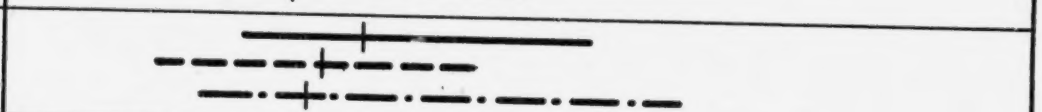
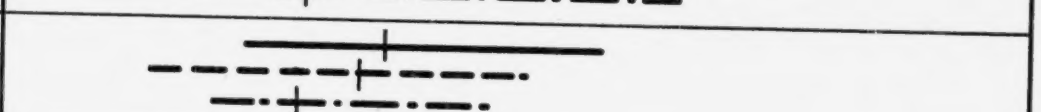
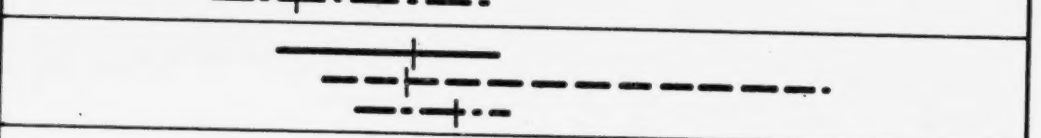
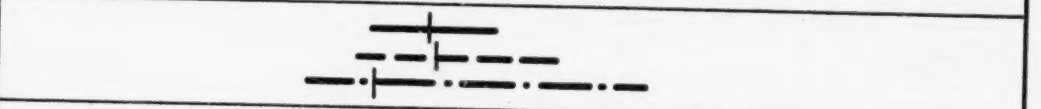
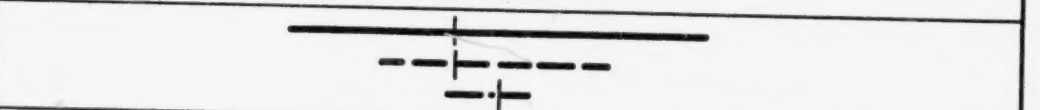
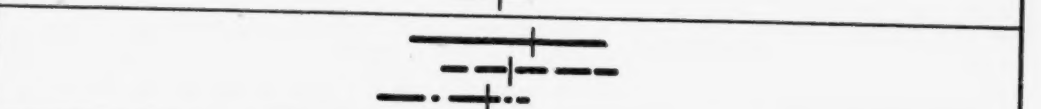
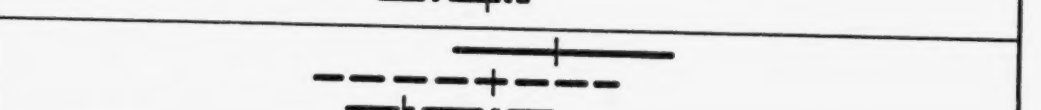
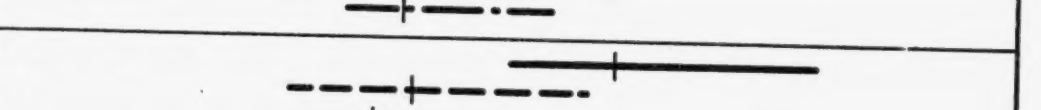
| RESPONSE | OBSERVED IN | TOTAL N | MEDIAN AND RANGE OF DATES OF FIRST OCCURRENCE (DAYS) 20 40 60 80 100 120 140 160 180 200 |
|---|---|---|---|
| SWIPES AT OBJECT | 11 | 14 |  |
| UNILATERAL HAND RAISING | 12 | 13 | |
| BOTH HANDS RAISED | 12 | 13 |  |
| ALTERNATING GLANCES (HAND AND OBJECT) | 10 | 11 |  |
| HANDS TO MIDLINE AND CLASP | 7 | 10 | |
| ONE HAND RAISED WITH ALTERNATING GLANCES, OTHER HAND TO MIDLINE CLUTCHING DRESS | 5 | 9 |  |
| TORSO ORIENTED TOWARDS OBJECT | 4 | 9 | |
| HANDS TO MIDLINE AND CLASP AND ORIENTED TOWARDS OBJECT | 3 | 9 |  |
| PIAGET-TYPE REACH | 6 | 9 |  |
| TOP LEVEL REACH | 9 | 9 |  |

FIGURE 7

## COMPARISON OF PREHENSORY RESPONSES AMONG ALL GROUPS

| RESPONSE | OBSERVED IN | TOTAL N | MEDIAN AND RANGE OF DATES OF FIRST OCCURRENCE (DAYS) 20 40 60 80 100 120 140 160 180 200 220 |
|---|---|---|---|
| SWIPES AT OBJECT | 13<br>11<br>14 | 13<br>14<br>16 |  |
| UNILATERAL HAND RAISING | 15<br>12<br>13 | 15<br>13<br>16 |  |
| BOTH HANDS RAISED | 16<br>12<br>13 | 18<br>13<br>16 |  |
| ALTERNATING GLANCES (HAND AND OBJECT) | 18<br>10<br>12 | 19<br>10<br>14 |  |
| HANDS TO MIDLINE AND CLASP | 15<br>7<br>10 | 15<br>10<br>14 |  |
| ONE HAND RAISED WITH ALTERNATING GLANCES, OTHER HAND TO MIDLINE CLUTCHING DRESS | 11<br>5<br>7 | 19<br>9<br>14 |  |
| TORSO ORIENTED TOWARDS OBJECT | 15<br>4<br>5 | 18<br>9<br>12 |  |
| HANDS TO MIDLINE AND CLASP AND ORIENTED TOWARDS OBJECT | 14<br>3<br>4 | 19<br>9<br>12 |  |
| PIAGET-TYPE REACH | 12<br>6<br>8 | 18<br>9<br>13 |  |
| TOP LEVEL REACH | 14<br>9<br>13 | 14<br>9<br>13 |  |

CONTROL AND HANDLED
MASSIVE ENRICHMENT
MODIFIED ENRICHMENT

FIGURE 8